SOIL SURVEY AROUND IMPERIAL, CALIFORNIA.

By THOMAS H. MEANS and J. GARNETT HOLMES.

INTRODUCTION.

The part of the Colorado Desert investigated by this Bureau extends from the international boundary line at the town of Calexico northward 21 miles. The area includes about 169 square miles, is entirely within San Diego County, Cal., and lies about 115 miles east of the city of San Diego. Yuma, Ariz., is about 60 miles to the eastward. The nearest railroad is the main line of the Southern Pacific, about 45 miles north of Calexico. (See fig. 20, p. 447.)

The desert was entered the latter part of October, and two months were spent in detail work, during which time about 165 square miles were surveyed. It was not possible to spend sufficient time to make a detailed study of the entire area already taken up and proposed to be cultivated.

Throughout the area mapped samples were collected, reaching to a depth of at least 6 feet, and examined by the electrical method to determine the percentage of alkali salts. Careful note was made of the conditions between the points of sampling, and from these data the soil map and alkali map were constructed. Other borings to a depth of 18 feet were taken at a few places over the country to determine the amount of alkali in the deeper subsoil. In the field about 900 samples of soil were examined for alkali. A number of samples were sent to the laboratories in Washington for examination, for additional determinations regarding the kind of alkali carried, and for mechanical analysis.

The demand for information concerning this area was so great that a preliminary circular containing the principal part of this report was prepared and issued January, 1902, as Circular No. 9, Bureau of Soils. This circular contained maps reduced from those accompanying this report and had appended in addition to the information in this report a table showing the per cent of alkali in each foot of depth of the borings.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

Ever since the Colorado Desert was surveyed in 1854, schemes have been discussed to bring the water of the Colorado River onto the land.

Actual work on surveys began in 1891, when Mr. C. R. Rockwood became identified with a company whose first plans were to take the water out a few miles above Yuma and carry it down by canal and across the river by flume, the water to be used on lands in Mexico. In the financial panic of 1893 this company went to pieces, and the difficult engineering features of the project prevented it from again being seriously discussed. With great tenacity of purpose Mr. Rockwood continued to devote his time and whole energies to interesting capital in irrigating at least a part of the desert, and the result was the formation in 1900 of the California Development Company. This company is a corporation in both the United States and Mexico, since a part of the company's works and canals are in Mexico.

The California Development Company is a stock company, the shares of which may be disposed of at will by the owners. It is not the policy of the company to actually irrigate lands in the United States, but to sell water to mutual irrigation companies at the border line, these companies having contracts which specify that not more than 50 cents per acre-foot will ever be charged for water and that at least one acre-foot of water must be used each year. These mutual companies are made up of the owners of the land who have purchased water stocks from the California Development Company, which stocks are made appurtenant to the land. Water stocks began selling at $8.75, with a $1 bond, acceptable as future payment on stock, issued for each of the three dollars of the first payment, making these stocks actually cost but $5.75 per acre. The demand for lands and stocks was so great that the company raised the price from time to time until now (January, 1902) stocks are selling for $20 per share, the money to be paid in yearly installments. For the price paid for stock the California Development Company builds all canals, so that when the mutual companies assume control in the different districts they will have the systems of canals all constructed. An assessment will be made by these companies for running expenses, which must be paid by the farmer in addition to the 50 cents an acre per foot for water.

THE IRRIGATION SYSTEM AS PLANNED.

The heading for the canal is 7½ miles below Yuma, on the California side of the river. The water will be carried from this point in a large canal, or several smaller parallel ones, a distance of 8 miles to the channel of the Salton River, where the natural channel is used to carry the water about 60 miles northward, running through a tract of 100,000 acres in Mexico (owned by the California Development Company), to the area to be irrigated. It will be taken out of the Salton a little way below the international boundary line and carried into the United States in a large 60-foot bottom canal, with a capacity of 25,000 inches, or 5,000 second-feet. This canal is intended to irrigate that part of the delta included between Salton and New rivers. After

entering the United States for a short distance this large canal is to be changed into two 30-foot canals, side by side, the object being to use one while the other is being cleaned. Other canals are planned to leave the Salton at various points to irrigate land in Mexico as well as on the east side of Salton River and west side of New River in the United States.

PRESENT DEVELOPMENT OF IRRIGATION SYSTEM.

Water was first brought to the area in June, 1901, in a small ditch along the route of the proposed larger one. This water is used for domestic purposes, the watering of stock, and for irrigating a small amount of land. The greater part of the main canal, to the point where the 30-foot canals commence, is finished. From this point one of the 30-foot canals is for the most part finished to Imperial and many of the laterals are constructed. The permanent heading at the Salton, 7 miles southeast of Calexico, consisting of a combined heading and 8-foot drop, has been built, but beyond this there are as yet no gates or checks in the main canal. In all likelihood no water except that in the small ditch will be available for crops the present season (1902).

CLIMATE.

The climate is that of a semitropical desert—very little rain, high temperatures in summer, and only light frosts in winter. Records of weather conditions have not been kept in the area for a period long enough to establish normals of rainfall or temperature, but along the Southern Pacific Railroad, 30 miles to the north of the area, observations have been carried on for a series of years, and it is believed that these records are nearly typical of the area surveyed. The following table shows the precipitation and temperature records at Salton and at Mammoth Tank:

Normal monthly and annual temperature and precipitation.

Month.	Temperature.		Precipitation.	
	Salton.	Mammoth Tank.	Salton.	Mammoth Tank.
	°*F.*	°*F.*	*Inches.*	*Inches.*
January	55.7	53.9	0.49	0.18
February	59.2	59.0	.74	.38
March	66.5	66.1	.24	.20
April	76.8	75.7	.00	.05
May	83.8	84.1	.08	.02
June	93.2	92.5	Tr.	Tr.
July	98.6	98.5	.18	.06
August	97.7	97.5	.12	.20
September	90.5	90.3	.15	.04
October	79.4	77.2	.11	.12
November	67.3	63.8	.13	.15
December	57.4	55.5	.66	.44
Normal annual	77.2	76.2	2.90	1.85

No reliable frost records are to be had. During the two years' observations at Imperial the thermometer has been as low as 19° once each winter. Possibly the portion of this desert below sea level is visited by more severe frost than the adjacent higher lying areas. Young blue-gum trees were injured by frost at Calexico in December, 1901.

High winds are said to be common during the winter months. Several winds occurred during the time the field party was on the desert. The storms last from one to three days, and the wind blows from 15 to 20 miles an hour, with gusts as high as 30 miles.

TOPOGRAPHY.

The area mapped is a part of the delta of the Colorado River. The surface in general is apparently level—a smooth, gently sloping plain, admirably adapted for irrigation. The general fall is about 5 feet to the mile. Over the greater part of the area between the Salton and New rivers no leveling whatever is necessary for irrigation, the surface being smooth, level, and practically devoid of vegetation.

Salton River enters the United States at the southeast corner of T. 17 S., R. 15 E., and flows in a general northerly direction to a point north of the area mapped, where it turns northwest and eventually empties into Salton Sink. For the first 25 miles of its course in the United States its banks are low, but farther north bluffs 40 to 60 feet high are found on each side. New River crosses the international boundary 7 miles west of the Salton, flows northwest for 7 miles, makes a great bend toward the west, and flows back northeast, cutting the area mapped in the northwest corner of T. 14 S., R. 14 E. The large area between the two rivers is considered the best part of the delta in this country. Both the rivers are dry except in time of the highest floods in the Colorado, when water breaks over the divide and runs in them for a short time.

The areas shown on the soil map as Dunesand are covered with dunes and hummocks 3 to 15 feet in height. The leveling of such land will be found expensive, and at the present prices of land will not prove profitable. However, should transportation facilities become better and land under cultivation bring a higher price than is now the case, much of this dune land can be leveled and reclaimed. By far the greater part of the dunes are free from harmful quantities of alkali salts, and the porous nature of the material will prevent the rise of the alkali if the level of standing water is kept so low that the upward capillary movement is unable to raise the water from the water table to the surface of the ground.

Around the western, southern, and southeastern sides of Mesquite Lake the lands are in places badly gullied and the amount of good land is small. With these few exceptions the land of the desert is

0 Feet High on New River, 10 Miles Northwest of Imperial.

very level and requires but the throwing up of small levees to permit irrigation.

The topography is shown by the contour lines upon the soil map. These contour lines are made from levels along section lines, and therefore do not show the minor details of topography. We are indebted to the California Development Company for the base and topographic map.

All of this part of the delta is below sea level. The basin extends to Salton Sink, which is about 280 feet below sea level. The basin is surrounded by a well-defined beach line, which is approximately at sea level, showing that there has been very little accumulative elevation or depression since the basin was a part of the ocean. The favored explanation of the formation of the country is that the Colorado River filled in the basin near its mouth, the greater deposition being nearest the river, until this part of the sea was cut off and became an inland lake, from which the water has evaporated. There are a number of beach lines below the one at present sea level, and these lower beaches are taken as evidence that the basin has been partially refilled at various times, the water remaining at one level long enough to form a beach.

In a study of the alkali of the area it was important to determine, if possible, whether the soils were deposited in fresh, brackish, or salt water. The bottom of the basin near Salton is covered with a thick layer of salts, very largely sodium chloride. This is undoubtedly from the evaporation of sea water. Over the surface of the desert throughout the area surveyed are found shells. Mr. C. A. Simpson, of the Smithsonian Institution, has kindly identified these shells for this Bureau. The most common are a mussel shell (*Anodonta*) and a small spiral shell (*Trionia*), sometimes so abundant as to blow up in little windrows or drifts. Three other varieties (*Physa*, *Planorblis*, and *Gnathodon*) are less common. All of these shells are of species now living and are found in fresh or, possibly, slightly brackish water. These unquestionably point to fresh-water origin for at least the surface material on the desert. Other observations bear out this conclusion, so it would seem that the waters of the Colorado River have been largely responsible for the sands and clays at present on the surface.

SOILS.

The soils of this portion of the delta are very uniform, all having been formed principally by the deposition of the finer sediment of the Colorado River. In some places sand has been mixed with this finer soil, making a sandy loam, or even in small areas a sand.

Five types were recognized and mapped, all of which are in places excessively alkaline, and even in places where the surface 6 feet shows no accumulation the soil is underlain by an alkali-bearing clay subsoil.

The following table shows the areas of each type of soil:

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Dunesand	29,840	27.7	Imperial loam	30,410	28.0
Imperial sand	1,020	1.0	Imperial clay	23,120	21.4
Imperial sandy loam	23,710	21.9	Total	108,100	......

DUNESAND.

The sand dunes of the area mapped are found along the eastern boundary, limiting the irrigable land along Salton River. The dunes are from 2 to 10 feet high, crescent shaped, and very rough and irregular. They have been formed by the strong winds of the valley. The sand is of a reddish brown color, rather rotten, and often mixed with small particles of flocculated soil. When wet these particles break down, producing a sandy loam soil. These dunes are underlain by the heavier soil material of the delta.

Owing to the strong winds which have formed these dunes and which would blow the sand around if leveled, and the roughness of the country, requiring great expense for leveling it, it is doubtful if these sand dunes are of present agricultural value.

The Dunesand is usually free from alkali, 95 per cent of the soil carrying less than 0.2 per cent alkali, but directly south of Mesquite Lake there is an area of Dunesand, the western part of which contains a high percentage of alkali.

Aside from the dunes and the small area of Imperial sand, the presence of sand in either soil or subsoil is unusual, except along the rivers. In a few borings sand was encountered in the subsoil. Should such areas of sand subsoil be extensive, the drainage problem would be much simplified. The work done on the desert, however, shows no large areas of sand subsoil.

The mechanical analyses of the Imperial sand, shown in the following table, will answer for the Dunesand. They show the sand to be of very fine grade, with enough silt and clay to render it retentive of moisture. This texture is admirably suited to the growing of alfalfa, fruit, or, for that matter, of almost all crops suited to the climate of the district.

Much of this Dunesand is susceptible of leveling, but the cost is great. Estimates of $20 to $30 per acre are given for much of the land; some of it can be reclaimed at a lower figure. Should it happen that this expenditure in preparing the land for crops is warranted, part of this Dunesand can be brought under cultivation and will prove the easiest soil of the desert to manage.

IMPERIAL SAND.

The Imperial sand is found only in small areas, and is composed of the same material as the sand dunes, the principal difference being that the surface is smooth enough to readily permit of leveling for irrigation. It is usually found in the vicinity of the dunes. Only small isolated areas were mapped. The surface soil is sand, on the average 5 feet deep, underlain by loam or clay loam which contains alkali. This soil will undoubtedly prove to be the best in the valley for all of the garden crops, or any crop requiring cultivation.

This soil will very likely always be well drained and practically free from alkali salts, but if the subsurface water should rise to within 6 or 8 feet of the surface by reason of excessive irrigation there would be great danger of the accumulation of alkali. The cultivation of the sand is safe at present, but the movements of water and alkali salts in it are rapid, and it should be handled with great care.

Eighty-two per cent of the soil has less than 0.20 per cent alkali and 18 per cent from 0.20 to 0.40 per cent alkali.

The following table shows the results of a mechanical analysis of this soil and of the loam subsoil. No chemical analyses were made, but there is no reason to believe that the soil is in any way deficient in plant food. Carbonate of lime is present in abundance.

Mechanical analyses of Imperial sand.

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6288	NE. cor. sec. 28, T. 16, S., R. 15 E.	Sand, 0 to 48 inches.	0.06	3.90	Tr.	0.70	0.76	28.18	40.40	19.60	6.18
6289	Subsoil of 6288....	Loam, 48 to 72 inches.	.20	5.86	0.00	.40	.30	6.24	12.58	43.30	31.50

IMPERIAL SANDY LOAM.

This soil is found scattered pretty generally throughout the area mapped, there being in all 37 square miles, or 24,000 acres. As a rule the surface is covered with small dunes, which consist of the sandy loam soil blown by the wind and lodged beside bushes and other obstructions. In T. 16 S., R. 15 E.; T. 16 S., R. 14 E., and T. 15 S., R. 14 E. the surface is wind scored and very irregular, while along the bluff southwest of Mesquite Lake, in T. 15 S., R. 14 E., the land is much cut by gullies, in some places 8 or 10 feet deep.

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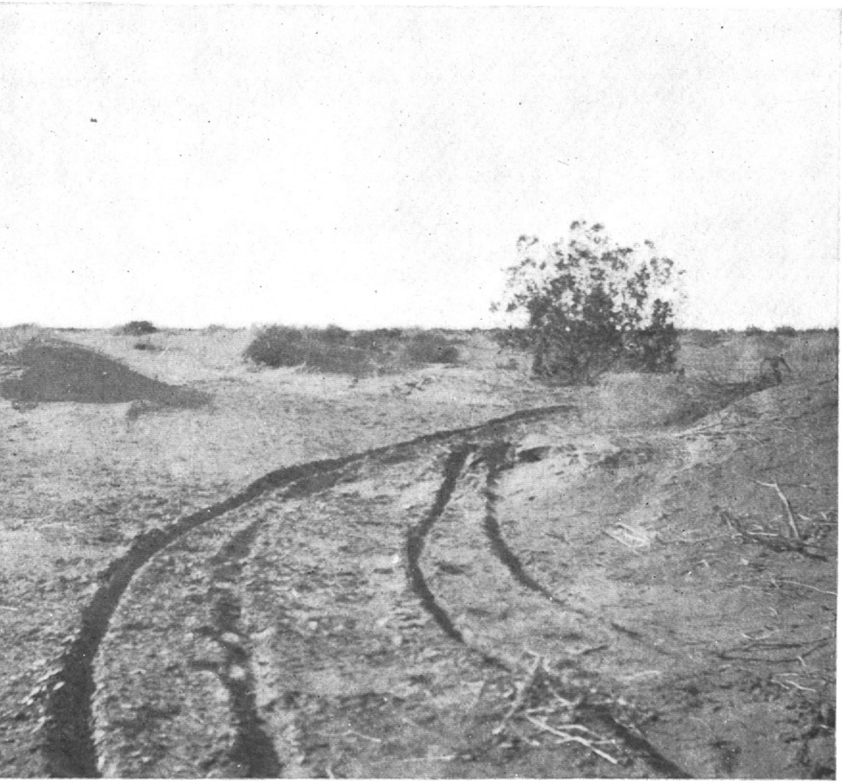
The sandy loam soil is formed by the coarsest particles of the Colorado River deposit mixed with wind-blown sand. The sandy loam extends to a depth of 3 feet and is underlain by a loam or heavy loam. This soil will take water readily, and where level and free from alkali is adapted to cultivated crops or alfalfa. Some of the best, and some of the worst, lands of the valley are composed of this type. A reference to the alkali map will show that this soil ranges in alkali content from practically nothing to more than 1 per cent. Thirty-seven per cent of the soil has less than 0.20 per cent alkali, 21 per cent has from 0.20 to 0.40 per cent, and 42 per cent has more than 0.40 per cent alkali.

The mechanical analyses which appear below show this soil to be in some places a very heavy sandy loam. There is a great deal of carbonate of lime and gypsum in the soil, and in its natural condition the fine soil grains are cemented together by the lime carbonate or gypsum, which gives the soil a light appearance. In shaking with water in the mechanical analyses this cementing material is dissolved and the fine grains thus liberated show the soil to be heavy in texture. Therefore it may be assumed that upon irrigation this soil will become heavier than it now appears in the field.

Mechanical analyses of Imperial sandy loam.

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6295	NE. cor. sec. 5, T. 15 S., R. 14 E.	Fine sandy loam, 0 to 24 inches.	2.10	5.24	0.00	0.26	0.36	13.64	29.10	46.06	5.10
6290	NW. cor. sec. 25, T. 16 S., R. 14 E.	Sandy loam, 0 to 36 inches.	.90	4.14	Tr.	.40	.36	17.74	35.64	30.68	10.00
6297	NE. cor. sec. 16, T. 15 S., R. 14 E.	Sandy loam, 0 to 48 inches.	.74	5.66	.00	Tr.	.42	3.10	14.24	64.40	12.74
6293	NE. cor. sec. 2, T. 17 S., R. 14 E.	Sandy loam, 0 to 36 inches.	.08	5.62	.00	.34	.36	7.88	19.08	45.00	21.68
6298	NE. cor. sec. 29, T. 14 S., R. 14 E.	Sandy loam, 0 to 36 inches.	5.50	10.20	.00	.16	.80	4.44	3.50	51.58	27.54
6299	Subsoil of 6298..	Loam, 36 to 72 inches.	2.40	8.34	Tr.	.24	.38	1.22	2.02	57.68	29.62
6294	Subsoil of 6293..	Clay loam, 36 to 72 inches.	.16	6.38	.00	.16	.06	.98	7.48	45.56	39.20
6296	Subsoil of 6295..	Clay, 36 to 72 inches.	1.60	8.94	.00	.26	.32	1.34	1.56	37.36	48.72



Imperial Sandy Loam covered with small Dunes.

IMPERIAL LOAM.

The Imperial loam was found to comprise a part of each township mapped. The surface is smooth, level as a floor, and almost devoid of vegetation. It has the peculiar slick, shiny appearance often seen in localities where water has recently stood. It is the direct sediment of the Colorado River, which was deposited in strata when the area was under water. These strata are from 0.01 inch to 2 or 3 inches thick, very much resembling shale; in fact, to all external appearances being exactly similar. When water is applied, however, the soil softens up and is a reddish sticky loam, a little heavier than a silt loam. It is from 4 to 6 feet deep, underlain by a clay or clay loam, and contains considerable organic matter, including an abundance of nitrogen and potash. When free from alkali it is well adapted to the growing of wheat, barley, and alfalfa. This soil is in the main alkaline and in some places to such a degree as to preclude all possibility of profitable agriculture. Of the 30,000 acres mapped 16½ per cent has less than 0.20 per cent alkali; 21½ per cent has from 0.20 to 0.40 per cent, while 62 per cent has more than 0.40 per cent alkali.

Mechanical analyses of Imperial loam.

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6282	NW. cor. sec. 30, T. 16 S., R. 14 E.	Loam, 0 to 36 inches.	0.18	6.56	0.00	0.14	0.04	0.30	6.50	64.74	21.44
6285	NE. cor. sec. 29, T. 16 S., R. 14 E.	Loam, 0 to 36 inches.	.18	5.72	.12	.50	.56	5.26	13.40	41.72	32.66
6287	NE. sec. 21, T. 16 S., R. 15 E.	Loam, 0 to 36 inches.	.18	6.70	.00	.14	.08	3.80	4.40	49.20	35.64
6283	Subsoil of 6282....	Fine sand, 36 to 60 inches.	.10	4.88	.00	.18	.14	.60	12.04	69.20	12.86
6284	Subsoil of 6282....	Clay loam, 60 to 108 inches.	.21	7.00	.00	.22	2.26	.86	3.50	52.74	35.32
6286	Subsoil of 6285....	Clay loam, 36 to 72 inches.	.31	7.06	.00	.00	.10	1.22	4.54	46.58	40.36

IMPERIAL CLAY.

The Imperial clay as soil or subsoil is found throughout the entire area. It is usually comparatively level, although in some places small hummocks have been blown up on its surface. It is this soil that surrounds both the towns of Calexico and Imperial, the only difference in

the soils of the two districts being in the alkali content. The soil has been formed by the deposition of the finest sediment of the Colorado River and is stratified in the same way as the loam. It is a heavy, sticky, plastic soil, very much resembling the clay subsoil found in the Mississippi River Delta. When dry and in its natural state it exists in hard cakes and lumps, which may be cut with a knife and are susceptible of taking a high polish. When wet the lumps are very plastic and sticky, making a soil which is very refractory and difficult to cultivate. Upon drying the soil becomes very hard and cracked. Sorghum and millet were grown this year on several hundred acres of this land in the vicinity of Calexico, and produced good crops. The sorghum, however, was the best, the yield being 6 or 8 tons to the acre.

Cultivation of this clay soil will be very difficult. A similar soil is found in the Salt River Valley as a phase of the Glendale loess and is locally known as "slickens." The farmers of that neighborhood have considerable difficulty in managing this soil, and it is not as refractory as much of the Imperial clay. Either annual crops or crops which can be cultivated throughout the growing season are productive of best results on this soil, for the heavy and hard crusts need to be broken up and thoroughly pulverized occasionally. Alfalfa does not do well on such a soil, for the crusts seem too hard and the soil too dense and impenetrable to permit the constant extension of the fine rootlets so essential to permanency in an alfalfa field. Deep plowing and thorough cultivation will in a few years greatly improve this soil.

Aside from the difficulties of cultivation due to the physical properties of the soil, the greater part of it contains too much alkali to allow its continued cultivation. Two or three crops may be taken off the land, but the rise of the alkali is almost inevitable, and the cultivation of areas of this soil containing more than 0.40 per cent alkali is not safe.

In the area surveyed there were 23,000 acres of Imperial clay. Of this, 3 per cent carried less than 0.20 per cent alkali, 43 per cent carried from 0.20 to 0.40 per cent, and 54 per cent had more than 0.40 per cent alkali.

Crop of Sorghum on the Imperial Clay near Calexico.

Character of Imperial Clay.

Mechanical analyses of Imperial clay.

No.	Locality.	Description.	Soluble salts, as determined in mechanical analysis.	Organic matter and combined water.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6277	SW. cor. sec. 10, T. 17 S., R. 14 E.	Clay loam, 0 to 72 inches.	0.22	6.64	0.00	0.24	0.38	1.32	3.42	51.60	36.78
6280	NE. cor. sec. 12, T. 14 S., R. 14 E.	Clay loam, 0 to 72 inches.	.37	7.76	.22	.50	.20	.80	2.14	41.58	47.46
6274	SW. ¼ sec. 18, T. 17 S., R. 15 E.	Clay, 0 to 36 inches.	.12	5.46	.36	1.56	1.64	11.58	4.10	26.00	49.72
6278	NE. cor. sec. 29, T. 14 S., R. 14 E.	Clay loam, 0 to 72 inches.	1.30	7.88	.00	1.36	1.26	2.78	2.24	27.60	56.90
6275	Subsoil of 6274....	Clay loam, 36 to 72 inches.	.24	6.26	.00	.26	.48	2.84	6.14	34.18	49.36

WATER SUPPLY.

The water supply for irrigation in the desert is entirely from the Colorado River below Yuma. Much has been said and written about the value of this water for irrigation purposes. Two analyses of the water of the Colorado River were made in this Bureau, the results appearing in the table below:

Analyses of soluble matter in Colorado River water.

Constituent.	Calexico from ditch, Nov., 1901.	Headgate, Nov., 1901.
	Parts per 100,000.	*Parts per 100,000.*
Ions:		
Calcium (Ca)	12.10	9.99
Magnesium (Mg)	2.90	2.59
Sodium (Na)	15.20	9.70
Potassium (K)	3.20	5.40
Sulphuric acid (SO_4)	41.03	33.99
Chlorine (Cl)	16.08	12.12
Bicarbonic acid (HCO_3)	16.89	13.30
Conventional combinations:		
Calcium sulphate ($CaSO_4$)	41.10	33.67
Magnesium sulphate ($MgSO_4$)	14.30	12.89
Sodium sulphate (Na_2SO_4)	.79	....
Potassium chloride (KCl)	6.09	10.19
Sodium chloride (NaCl)	21.82	13.85
Sodium bicarbonate ($NaHCO_3$)	23.30	21.00
Total in solution	107.40	87.10

The amount of soluble matter indicated by these analyses is not large enough to cause damage in the use of this water for irrigation purposes. The lime and potash which the water contains are valuable additions to the soil, though the soils at this time do not need such fertilizing material. Perhaps the most valuable part of the water is the silt or mud held in suspension. The water as it leaves the river is very muddy. Prof. Robert H. Forbes, of the Arizona Experiment Station,[a] examined the water of the Colorado River at Yuma, October 14 to 20, 1900. He found the silt to amount to 7.88 per cent and calculated the value on the market prices of fertilizers as $8.54 per acre-foot. He further states, "muddy water has its disadvantages. Ditch cleaning is a serious item of expense to canal companies and to farmers, amounting, for instance, to about $3,500 a year for the 50 miles of main ditch belonging to one of the Salt River Valley canals.

"Tender vegetation, also, such as young alfalfa, is often destroyed by a coating of mud on the leaves; but with the furrow method of irrigation, where available, and other precautionary measures, the damage from this cause may be greatly lessened."

Though at the present time the soils of the Colorado Desert lack little in the way of plant food, irrigation with such water will undoubtedly maintain the fertility permanently.

Much of the silt is settled out of the water in the 60 miles of cana in Mexican territory, so that the fertilizing value of the water as it enters the land is not so great as when it leaves the river.

Furrow irrigation should not be practiced upon alkali lands; flooding is the method to be used. On the lands free from alkali, however, furrow irrigation will be found very effective and generally better than flooding.

ALKALI IN THE SOILS.

By popular usage any harmful accumulation in the soil of salts of any kind is referred to as alkali, distinctions being made between districts containing a large amount of sodium carbonate and those which do not. The sodium carbonate areas are popularly called "black alkali" areas, and all others "white alkali" areas. The white alkali salts are usually found associated with the sodium carbonate in black alkali areas, while in the white alkali regions there is usually a predominance of the sulphates or chlorides, with smaller amounts of other salts. So far as is yet known, the amount of white alkali that crops will withstand is influenced more by the presence or absence of lime as a constituent of the soil than by the chemical composition of the salts. It has been determined by experiment, both in the field and in the laboratory, that where there is an excess of lime in the soil in the form of sulphate or carbonate, plants will withstand a greater percent-

[a] Arizona Experiment Station, Timely Hints, No. 35.

age of alkali than where the lime content is small. In the Colorado Desert gypsum (sulphate of lime) and carbonate of lime are nearly always present in the soil.

In studying the alkali of the soils of the Imperial area, samples were taken at intervals to a depth of 6 feet and the percentage of alkali determined by the electrical method in use in this Bureau.

As a check upon the accuracy of the electrical instrument samples were collected at a number of places and the percentage of salts determined by the chemical method.

The alkali maps were constructed in the field from observations made at the time of the survey. These maps of a necessity had to be generalized to a certain extent.

Very little of the land had been cultivated, and no doubt small spots of alkaline lands not found on the map will develop upon irrigation. In its present form the map represents the average conditions of the country to a depth of 6 feet.

In many places the alkali salts show plainly upon the surface of the ground either as a loose, powdery mulch, as "puffy" spots, or as saline incrustations. In many more places, however, the surface gives no indications of the amount of alkali present. Native vegetation, where such exists, is a help in estimating the amount of alkali in the soil. Too much dependence should not be placed upon vegetation, however, for a number of instances were observed where conclusions thus drawn would be very erroneous. As a general statement, however the presence of large and well-developed greasewood or creosote bush (*Larrea mexicana*) indicates land free from harmful quantities of alkali salts. Where greasewood is abundant the land generally contains less than 0.40 per cent alkali. Scattering bushes, however, have been observed growing on soil containing more than 1 per cent alkali. On the other hand, large, well-developed, or abundant bushes of the shad-scale (*Atriplex canescens*) generally indicate land with more than 0.40 per cent alkali. The dark-colored bush with rounded, juicy leaves which turn black in winter (*Sueda intermedia*), is not a safe guide by which to judge the alkali conditions. It is more frequently found bordering low spots and places where water sometimes stands. The Kern greasewood or pickle weed indicates land which contains so much alkali as to be practically worthless. Peppergrass indicates land in which the immediate surface of the ground is free from alkali, but is no guide to the conditions which exist below the immediate surface. Calit or pigweed generally indicates land which is wet or has been overflowed, and while generally growing on land free from alkali, it has been observed on land which has an alkali subsoil.

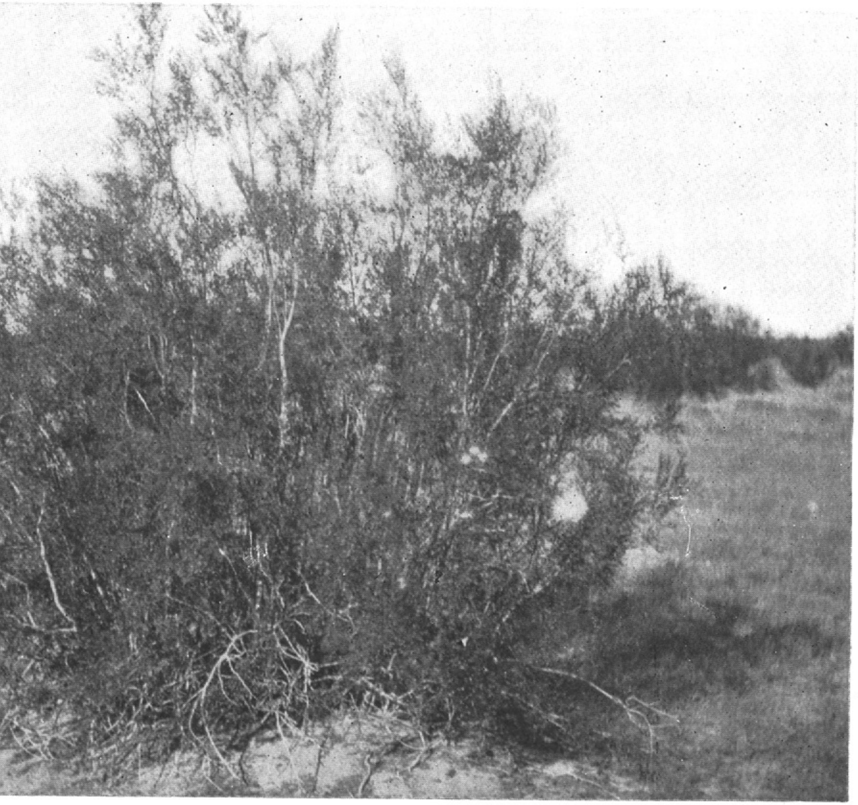
As a further indication it can be said that all land, except drifting sand, which is level and devoid of vegetation is open to suspicion, for nature has so many plants which have adapted themselves to arid and

desert places that the absence of all vegetation generally has some other cause than mere aridity.

A large number of samples of alkali crusts and of the various types of soil were collected and subjected to chemical analyses to determine the character and amount of the alkali salts. The following table gives the results of a number of these analyses:

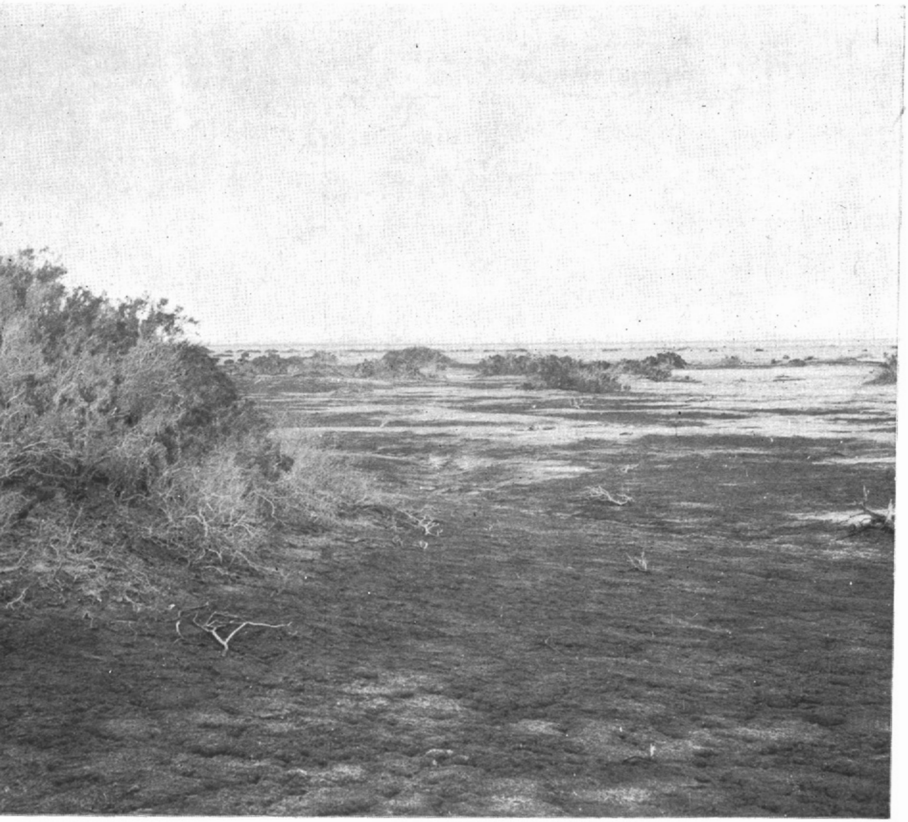
Chemical analyses of alkali in Imperial soils.

Laboratory No.	Location.	Depth.	Ca.	Mg.	K.	Na.	SO_4.	NO_3.	Cl.	HCO_3.
		Inch.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6309	SW. cor. sec. 13, T. 17 S., R. 14 E.	0–½	2.99	1.73	0.75	26.40	52.65	5.08	9.08	1.32
6308	NE. cor. sec. 29, T. 16 S., R. 14 E.	0–½	2.70	.52	1.09	29.37	28.62	10.68	22.91	4.11
6304	S. side sec. 31, T. 16 S., R. 14 E...	0–½	4.42	1.13	.57	27.38	26.94	11.23	25.65	2.68
6306	N. side sec. 19, T. 16 S., R. 13 E..	0–½	3.89	1.10	.50	29.11	25.96	8.45	30.73	.26
6307	NW. cor. sec. 14, T. 17 S., R. 14 E.	0–½	5.79	1.64	.33	27.04	20.04	6.97	37.73	.46
6305	NE. cor. sec. 14, T. 17 S., R. 14 E.	0–½	10.92	2.82	.47	19.92	8.40	11.22	45.88	.37
6302	SW. ¼ sec. 13, T. 17 S., R. 14 E...	0–½	6.05	2.36	.74	26.03	9.51	7.86	45.89	1.56
6316	3 mi. SE. Superstition Mountain.	0–2	8.35	.69	.50	27.15	4.89	6.62	51.22	.58
6303	SW. cor. sec. 13, T. 17 S., R. 14 E.	0–½	9.21	1.59	.46	25.03	7.02	3.79	51.99	.91
6314	NE. cor. sec. 36, T. 14 S., R. 14 E.	0–3	13.47	1.67	.45	20.78	2.80	3.90	56.58	.35
6313	NE. cor. sec. 29, T. 14 S., R. 14 E.	0–3	17.99	2.15	.45	14.86	2.61	5.12	56.59	.23
6315	3 mi. W. Imperial	0–2	20.12	.71	.60	14.80	.58	5.94	56.83	.42
6300	NE. cor. sec. 9, T. 14 S., R. 14 E..	0–24	12.66	1.68	3.37	12.66	34.19	......	10.12	25.32
6285	NE. cor. sec. 29, T. 16 S., R. 14 E.	0–36	8.14	1.35	3.62	18.10	28.06	......	10.86	29.87
6286	Subsoil of 6285..................	36–72	11.79	2.35	8.07	12.47	18.53	......	30.64	16.15
6274	SW. ¼ sec. 18, T. 17 S., R. 15 E...	0–36	5.69	3.10	11.40	11.41	10.36	......	14.52	43.52
6281	N. side sec. 16, T. 14 S., R. 14 E..	0–72	13.94	2.78	7.31	8.36	30.32	......	19.52	17.77
6276	E. side sec. 7, T. 17 S., R. 14 E..	0–36	6.14	4.46	2.23	20.12	14.52	......	22.35	30.18
6277	SW. cor. sec. 10, T. 17 S., R. 14 E.	0–72	6.52	4.34	7.60	12.50	13.58	......	22.84	32.62
6279	NE. cor. sec. 21, T. 14 S., R. 14 E.	0–36	9.67	1.50	5.80	16.56	32.07	......	24.08	10.32
6280	NE. cor. sec. 12, T. 14 S., R. 14 E.	0–72	9.38	2.16	5.05	16.61	24.18	......	25.29	17.33
6297	NE. cor. sec. 16, T. 15 S., R. 14 E.	0–48	8.13	2.55	9.79	16.98	5.34	.....	47.45	9.76
6298	NE. cor. sec. 29, T. 14 S., R. 14 E.	0–36	13.66	1.46	1.23	19.16	10.34	5.76	47.69	.70
6299	Subsoil of 6298..................	36–72	10.53	.60	1.92	22.99	20.76	......	41.04	2.16
6278	NE. cor. sec. 29, T. 14 S., R. 14 E.	0–72	7.58	5.01	3.38	18.99	7.85	......	51.50	5.69
6295	NE. cor. sec. 25, T. 15 S., R. 14 E.	0–36	14.51	3.66	1.35	16.26	2.55	......	59.28	2.39
6296	Subsoil of 6295..................	36–72	6.70	.87	2.86	27.58	3.07	......	54.97	3.95

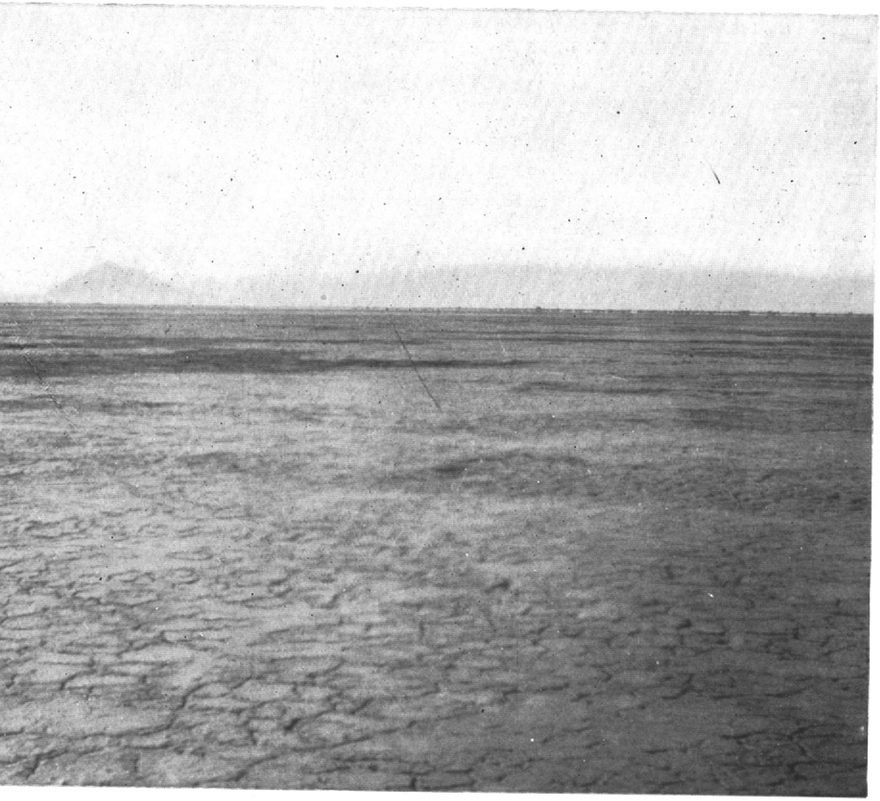


REOSOTE BUSH, OR GREASEWOOD, INDICATING LESS THAN 0.40 PER CENT OF ALKALI.

Shad-scale, indicating Land with more than 0.60 Per Cent of Alkali.



Strong Alkali Land West of Mesquite Lake.



HOWING PUFFY CHARACTER OCCASIONALLY SEEN. THREE MILES WEST OF IMPERIAL.

Alkali appearing on Ditch Bank near Calexico.

Theoretical percentage composition.

Laboratory No.	Location.	Per cent soluble.	$CaSO_4$.	$MgSO_4$.	Na_2SO_4.	K_2SO_4.	$CaCl_2$.	$MgCl_2$.	NaCl.	KCl.	$NaNO_3$.	$NaHCO_3$.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6309	SW. cor. sec. 13, T. 17 S., R. 14 E	13.49	10.17	8.57	55.84	1.67	......	......	14.94	......	7.00	1.81
6308	NE. cor. sec. 29, T. 16 S., R. 14 E	17.42	9.16	2.62	27.72	2.41	......	......	37.77	......	14.62	5.70
6304	S. side sec. 31, T. 16 S., R. 14 E	22.91	15.04	5.62	16.52	1.28	......	......	42.40	......	15.52	3.62
6306	N. side sec. 19, T. 16 S., R. 13 E	19.82	13.24	4.88	18.04	1.12	......	......	50.70	......	11.60	.42
6307	NW. cor. sec. 14, T. 17 S., R. 14 E	21.21	19.35	8.12	......	......	......	......	61.62	0.73	9.55	.63
6305	NE. cor. sec. 14, T. 17 S., R. 14 E	13.12	11.91	11.07	......	......	20.09	......	39.98	.89	15.42	.64
6302	SW. ¼ sec. 13, T. 17 S., R. 14 E	10.74	13.49	......	......	......	5.75	9.27	57.14	1.41	10.78	2.16
6316	3 miles SE. Superstition Mountain	9.48	6.92	......	......	......	17.45	2.72	62.03	.97	9.09	.82
6303	SW. cor. sec. 13, T. 17 S., R. 14 E	18.36	9.95	......	......	......	17.38	6.23	59.10	.89	5.19	1.26
6314	NE. cor. sec. 36, T. 14 S., R. 14 E	15.05	3.97	......	......	......	34.02	6.56	48.76	.85	5.35	.49
6313	NE. cor. sec. 29, T. 14 S., R. 14 E	15.30	3.69	......	......	......	46.60	8.44	33.08	.86	7.02	.31
6315	3 miles W. Imperial	11.22	.83	......	......	......	54.96	2.79	31.55	1.14	8.15	.58
6300	NE. cor. sec. 9, T. 14 S., R. 14 E	.47	42.62	5.06	......	......	......	2.95	8.01	6.33	......	35.03
6285	NE. cor. sec. 29, T. 16 S., R. 14 E	.44	27.60	6.33	5.43	......	......	......	12.67	6.78	......	41.19
6286	Subsoil of 6285	.59	26.26	......	......	......	11.11	9.10	16.15	15.15	......	22.23
6274	SW. ¼ sec. 18, T. 17 S., R. 15 E	.39	14.51	......	......	......	4.14	11.91	......	4.66	[a]29.01	35.77
6281	N. side sec. 16, T. 14 S., R. 14 E	.58	42.85	......	......	......	3.83	10.80	4.18	13.94	......	24.40
6276	E. side sec. 7, T. 17 S., R. 14 E	.36	20.66	......	......	......	......	17.32	15.64	4.46	......	41.92
6277	SW. cor. sec. 10, T. 17 S., R. 14 E	.37	19.02	......	......	......	3.26	16.85	1.63	14.68	......	44.56
6279	NE. cor. sec. 21, T. 14 S., R. 14 E	.93	32.91	11.18	......	......	......	1.72	29.04	10.96	......	14.19
6280	NE. cor. sec. 12, T. 14 S., R. 14 E	.55	31.77	3.61	......	......	......	3.97	27.09	9.74	......	23.82
6297	NE. cor. sec. 16, T. 15 S., R. 14 E	.86	7.44	......	......	......	16.74	10.00	33.72	18.61	......	13.49
6298	NE. cor. sec. 29, T. 14 S., R. 14 E	6.81	14.62	......	......	......	25.89	5.75	42.55	2.34	7.89	.96
6299	Subsoil of 6298	3.36	29.36	......	......	......	5.29	2.34	56.36	3.67	......	2.98
6278	NE. cor. sec. 29, T. 14 S., R. 14 E	1.48	11.11	......	......	......	12.06	19.65	43.10	6.36	......	7.72
6295	NE. cor. sec. 25, T. 15 S., R. 14 E	2.51	3.58	......	......	......	37.21	14.34	39.06	2.55	......	3.26
6296	Subsoil of 6295	1.82	4.28	......	......	......	15.17	3.40	66.39	5.38	......	5.38

[a] $KHCO_3$, potassium bicarbonate.

The analyses show the alkali to be of the same general type throughout the portion of the desert mapped. There is no black alkali present, and the universal presence of gypsum precludes all possibility of the formation of black alkali in well-drained and aerated soils.

The alkali crusts are composed of sulphates, chlorides, and nitrates of calcium and sodium with small quantities of bicarbonates, together with salts of magnesium and potassium. An interesting fact is the presence of considerable quantities of nitrates. In all samples of crusts examined nitrates were present.

The analyses of the soils shows the character of alkali to differ in several ways from the crusts. Lime and potassium are present in larger quantities, while the bulk of the soluble matter is in the form of bicarbonates. Nitrates are present only in small quantities. The amounts of potassium are large, and will no doubt play an important part in the fertility of the soils.

The alkali exists either in the soil or subsoil throughout the area mapped. In many places where the soil is of open, porous nature this alkali has been washed out of the surface soil down into the subsoil, and in the case of the more sandy soils will very likely stay in the subsoil too deep to damage shallow-rooted crops, unless the soils are so filled up with water that the capillary power of the sandy soils can raise the standing water to the surface.

The alkali map accompanying this report outlines five grades of soil as to alkali content, as follows:

Grade of soil.	Acres.	Per cent of the area.
From 0 to 0.20 per cent	42,220	39.1
From 0.20 to 0.40 per cent	25,320	23.4
From 0.40 to 0.60 per cent	23,040	21.3
From 0.60 to 1 per cent	5,220	4.8
Over 1 per cent	12,300	11.4

These grades represent the average for the surface 6 feet, tests having been made for each foot in depth and the arithmetical mean taken.

The 0 to 0.20 per cent grade is soil that is practically free from alkali. No crops but the most sensitive would be injured by this percentage. Almost all common crops will withstand from 0.20 per cent to 0.40 per cent. Barley, corn, alfalfa, watermelons, cantaloupes, most of the berries, grapes, figs, apricots, and peaches will do almost as well in this grade of soil as in lands that contain much less, the chief danger in growing fruits being the fact that their roots are liable to go deep into the subsoil and thus reach the alkali accumulated there. Alfalfa will barely grow in the 0.40 to 0.60 per cent soil, even when well matured. If once a stand is secured it will struggle along, unless there be a concentration caused by irrigation. Barley will produce a crop,

though the yield is not large. Pear trees will grow for a time at least, and if the subsoil be no worse than the surface, and no concentration near the surface takes place, they will thrive indefinitely.

All land that contains more than 0.60 per cent of alkali must be handled very carefully to produce any kind of crops except the most alkali-resistant. Careful and proper methods of cultivation may result in washing enough of the alkali of the surface 2 or 3 feet into the subsoil so that shallow-rooted crops, such as annuals, can be grown. But until this surface reclamation takes place only such crops as sorghum, date palms, and sugar beets can be grown. On all the soils that contain more than 1 per cent of alkali, date palms and saltbushes are the only crops that will thrive. In the Sahara date palms grow on lands said to contain as much as 3 per cent of alkali.

The alkali map shows the conditions to a depth of 6 feet only, but as alkali salts have been known to rise to the surface from much greater depths, it is important to know the amount of alkali in the deeper subsoils. For this purpose deep borings were taken at a number of places. The following table shows the result of these borings:

Results of deep borings.

[Per cent alkali in each foot of soil.]

Depth in feet.	Boring 12, SE. cor. sec. 12, T. 17 S., R. 14 E.		Boring 44, NW. cor. sec. 25, T. 16 S., R. 14 E.		Boring 92, SW. ¼ sec. 17, T. 17 S., R. 15 E.		Boring 95, NE. cor. sec. 19, T. 15 S., R. 14 E.	
		P. ct.		*P. ct.*		*P. ct.*		*P. ct.*
0 to 1	Loam	0.19	Sandy loam	−0.20	Loam	0.37	Clay loam	1.80
1 to 2	do	.27	do	− .20	do	.24	do	1.88
2 to 3	do	.25	Sand	− .20	Clay loam	−.20	do	1.85
3 to 4	Clay	.21	do	− .20	Sand	−.20	do	1.88
4 to 5	do	.28	do	− .20	do	−.20	do	1.23
5 to 6	Clay loam	.25	do	− .20	Loam	−.20	Loam	1.22
6 to 7	do	.24	do	− .20	Clay loam	−.20	do	1.40
7 to 8	Clay	.34	do	− .20	Clay	−.20	do	1.30
8 to 9	do	.36	Sandy loam	.82	do	.30	do	1.35
9 to 10	do	.37	Clay	+1.34	do	.40	do	1.30
10 to 11	Loam	.22	Sandy loam	.70	do	.54	do	1.10
11 to 12	Clay loam	.36	do	.62	do	.62	do	1.00
12 to 13	do	.50			do	.56	do	1.20
13 to 14	do	.48			do	.73	do	1.10
14 to 15	do	.39			Loam	.84	Sandy loam	.84
15 to 16					do	.67	do	.84
16 to 17							do	.96
17 to 18							do	.90

Inspection of this table shows that at every deep boring alkali was found in more or less harmful quantity in the subsoil. Even in boring 44, where the soil was light throughout the top 8 feet and free from harmful quantity of salt, as soon as the clay was reached, at 9 feet, a high percentage of alkali was found. The irrigation of such soil would be perfectly safe as long as the level of standing water did

not rise sufficiently for the surface to be kept wet by capillarity. Should this happen the rise of the alkali, even though buried 8 feet, would be certain.

Aside from the alkali, which renders part of the soil practically worthless, some of the land is so rough from gullies or sand dunes that the expense of leveling it is greater than warranted by its value. In the 108,000 acres surveyed, 29,840 acres, or 27.7 per cent, are sand dunes and rough land. Of the total area level enough to permit profitable cultivation, 17 per cent contains less than 0.20 per cent of alkali and 32 per cent contains from 0.20 per cent to 0.40 per cent. The remainder of the level land, or 51 per cent, contains too much alkali to be safe, except for resistant crops.

CONDITIONS OF AGRICULTURE AND POSSIBILITIES OF IMPROVEMENT.

Perhaps more than any other part of arid America this lower desert portion of the Colorado River delta must depend upon agriculture, and agriculture alone, for its support. The nearest mining territory in any direction is miles away. The climate is not such that tourists or pleasure seekers will help maintain the country, as is the case in many other parts of the Southwest. Every dollar obtained from the country must come from the soil. To grow crops successfully in an arid country two things are absolutely necessary—the proper kind of soil and water. Experience long ago demonstrated that the greatest problem confronting the farmer in arid countries is the danger from harmful accumulations or the rising of alkali salts. Case after case is on record where, either from the use of alkali-impregnated water or from the localizing of the small amount of alkali already in the soil, large areas have been ruined where, when irrigation began, there was no appreciable amount of alkali apparent in any of these soils. In nearly every irrigated region these alkaline areas seem to be a necessary adjunct. Much work has been done by the different experiment stations of the United States and this Bureau in the past few years in determining the amount of alkali various crops will withstand, and the following limitations have been established for the white alkali:

	Per cent.
Barley, sugar beets, sorghum	0.60 to 1.00
Alfalfa, wheat, corn	.20 to .40

Sorghum is an alkali-resisting plant and will very probably withstand more than sugar beets. By glancing at these figures and at the alkali map which accompanies this report it will be seen that on a great part of the lands of the area mapped even the most alkali-resistant plants will not grow at the present time, before any accumulation at the surface has taken place from evaporation or concentration of seepage waters. The subsoil of all the area is strongly impregnated

with salts, a part of which must, in all except the very sandy soils, eventually reach the surface and greatly interfere with agriculture.

When looked at rationally it is easy to understand why this country is alkaline. It is part of an old, desiccated sea bed and is all below the present sea level. The soils were deposited and saturated with sea water or brackish water, which evaporated and left them strongly impregnated with the salts in solution. The rainfall is so slight as never to penetrate the soils to any depth, so that very little salt has ever been washed out of them. Wells put down to subsurface water all over the valley find water which contains alkali—sometimes too much for domestic use. Salton salt works are at the bottom of the basin, where tons and tons of salt are taken from the surface of the ground each year, only to be replaced by the evaporation of seepage waters, which must, in part, be the drainage from this very country.

One hundred and twenty-five thousand acres of land have already been taken up by prospective settlers, many of whom talk of planting crops which it will be absolutely impossible to grow. They must early find that it is useless to attempt their growth. On the bad alkali lands they should try to grow only crops suited to such lands. Test plots will be of very little value except for the year in which they are made. The land may produce a crop for a year, or even two years, and then, having become thoroughly saturated, the alkali will rise and kill the crops. For the worst lands the best thing to do will be to immediately abandon them.

Much can be done to improve, at least temporarily, the alkali conditions of the delta soils by careful and intelligent methods of cultivation and irrigation. On the heavier soils as quickly as possible enough organic matter should be plowed under to ameliorate in a degree the impervious clay properties and allow a more rapid percolation of the water. Water should in all cases be applied to the surface. Only on the most sandy soils should furrow irrigation be practiced at all, for soon the furrows would be as white as the ditch banks already are throughout the district. The alkali is transported by the water; so if the water can be applied to the surface and be kept going down all the time, and the subsoil offers good drainage, then alkali lands can be reclaimed simply by copious surface flooding; but if, on the other hand, the soil be heavy and compact, and not conducive to rapid percolation, then the tendency will be to fill up the soil with water—the alkali going down for a while and then again coming to the surface at the rise of the water table. This action is especially harmful if the subsoil contains a greater percentage of alkali than the surface.

So the permanent reclamation of alkali lands depends wholly upon the drainage, natural or artificial. If the natural drainage is not good, then artificial drains must be introduced. For the heavier soils of the delta artificial drains would have to be so close together that

the expense would be too great to be practicable, at least for the present, so the natural drainage alone will have to be depended upon. Standing water at Calexico is less than 50 feet below the surface, while at Imperial it is less than 30 feet, and at this point moisture comes to within 5 feet of the surface. Nearly all this subsurface water is salty, so if the water from the surface reaches this and raises it before it drains several miles laterally, then the conditions will be aggravated rather than bettered. If the whole country is irrigated at the same time sufficiently to wash the alkali down below the reach of plant roots, then the subsoil of the whole country will be filled and lateral drainage be very slow. So it would seem that the reclamation of the lands already badly alkaline is almost a hopeless task.

No doubt the best thing to do is to raise crops such as the sugar beet, sorghum, and date palm (if the climate will permit), that are suited to such alkaline conditions, and abandon as worthless the land which contains too much alkali to grow those crops. There is not rain enough to grow saltbush without irrigation, but with irrigation it would do well, and serve as profitable food for cattle, sheep, or goats.

Growing the ordinary crops, fruit, or alfalfa will be impossible on much of the land in the desert, and risky on all, unless special precautions are taken to prevent the rise of the alkali. Of the level lands only 17 per cent have less than 0.20 per cent alkali, while 32 per cent have from 0.20 to 0.40 per cent. This 49 per cent of the area can be farmed to nearly all crops as long as the accumulation of the alkali at the surface is prevented. The remainder of the land, or 51 per cent, will have to be farmed to alkali-resistant crops. Even where farmed to resistant crops the greatest precaution should be taken to prevent an accumulation of alkali at or near the surface.

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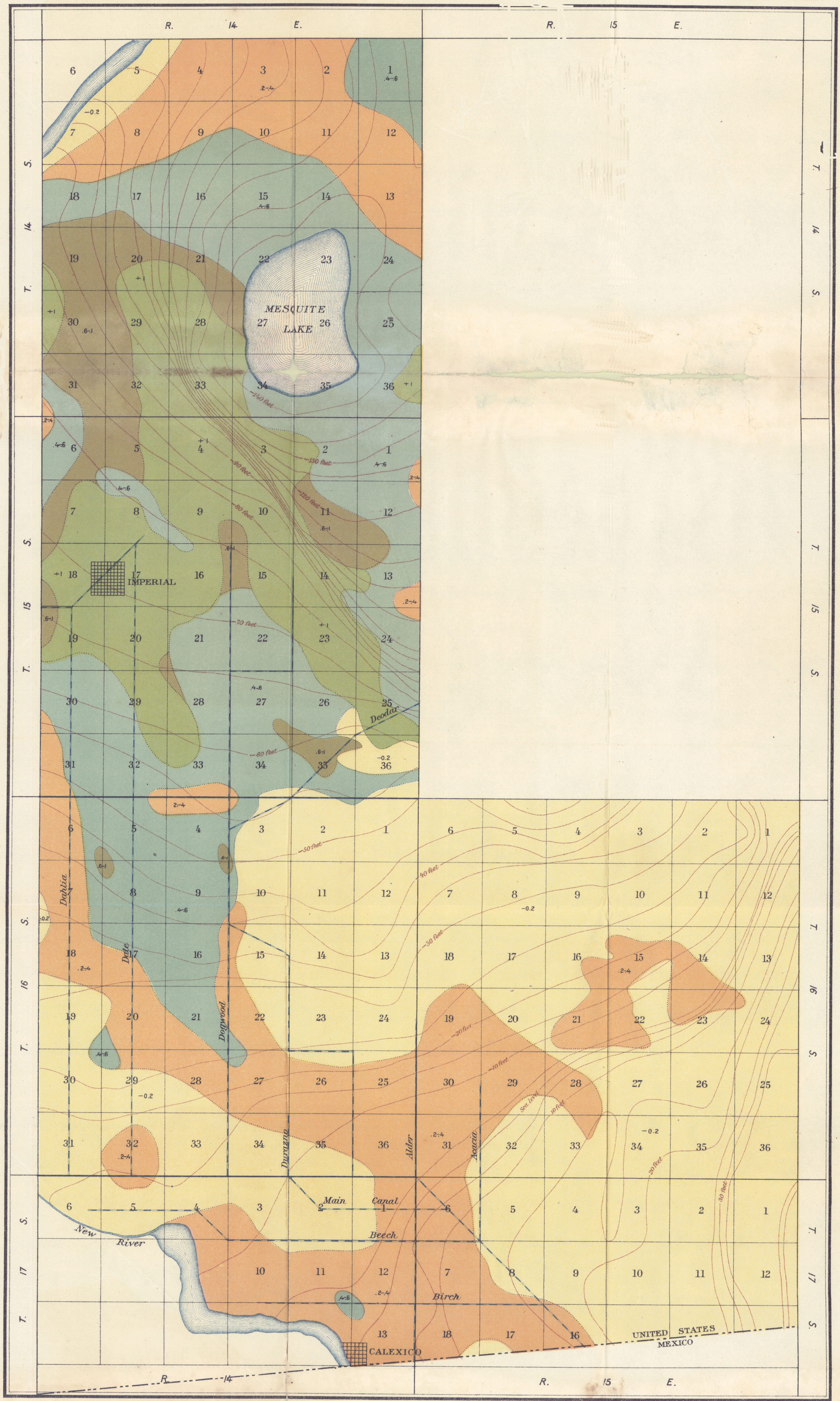
U.S. DEPT. OF AGRICULTURE
BUREAU OF SOILS
MILTON WHITNEY, CHIEF.

ALKALI MAP

CALIFORNIA
IMPERIAL SHEET



LEGEND

-0.2 Less than 0.2 per cent

.2-.4 From .2 per cent to .4 per cent

.4-.6 From .4 per cent to .6 per cent

.6-1. From .6 per cent to 1 per cent

+1. Over 1 per cent

Alkali Surveyed by
J. Garnett Holmes
1901

Scale 1 inch = 1 mile
Contour interval 5 feet.

Field Operations
Bureau of Soils
1901.

U.S. DEPT. OF AGRICULTURE
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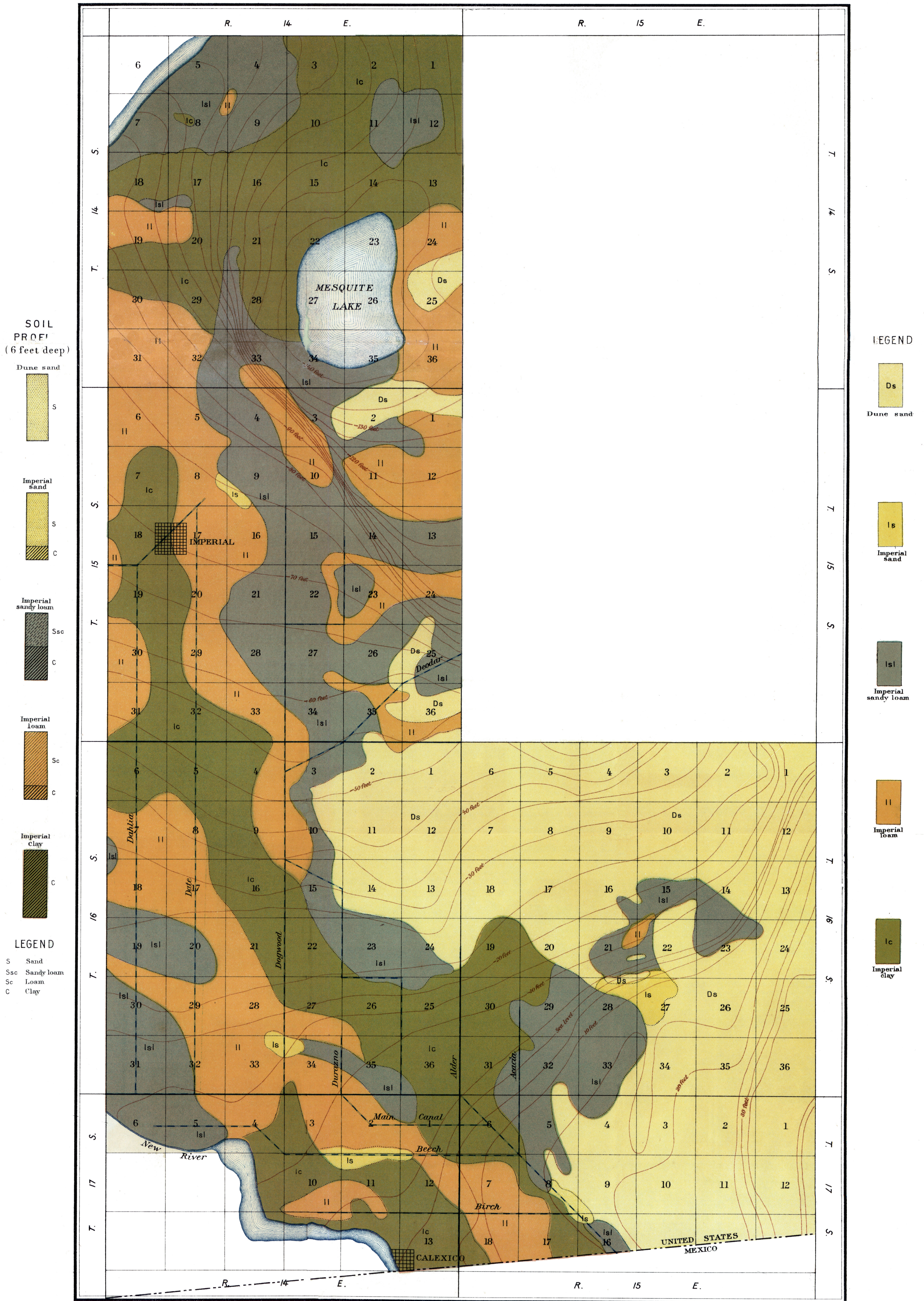
SOIL MAP

CALIFORNIA
IMPERIAL SHEET



Soils Surveyed by
J. Garnett Holmes
1901.

Scale ... mile